**Stratigraphy, Exploration and EOR potential of the Tensleep/Casper Formations, SE Wyoming**

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Search and Discovery Article #10851 (2016)**

Posted August 8, 2016

*Adapted from posters that were derived from oral presentation to Wyoming Geological Association, Casper, April 15, 2016.

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Abstract

The first theme of this poster presentation is to provide an update on the stratigraphy and sedimentology of the Tensleep/Casper Formation of Southeast Wyoming (and parts of Northern Colorado), and oil production from these rocks. We incorporate new measured sections, stratigraphic analysis and petrographic work undertaken by the authors. To this end we created a new database in ArcGIS (geographic information software) of tops and other information that updates the historical well database of the Wyoming Oil and Gas Commission archived in Casper. This new database has been used to create Common Risk Segment (CRS) maps of the Upper Tensleep oil play segment in Southeast Wyoming. These CRS maps indicate trends in Tensleep reservoir, charge, and trap that may be useful in planning further exploration. It is possible that use of advanced seismic acquisition or processing techniques applied over the complex structural terrains in high potential areas of SE Wyoming will produce new leads and, ultimately, new discoveries in addition to improved exploitation of existing oil fields. Indeed, the Play-Based CRS model we have used in this work may have relevance to re-consideration of mature regions in Wyoming or other states. In our effort, we essentially approached Southeast Wyoming the way we would approach a new area.

The second theme is to describe the occurrence in outcrop and core, of various flow units and discontinuities associated with depositional facies in the Tensleep. We continue to compile data on the abundance and arrangement of primary eolian strata and their role as key elements in reservoir heterogeneity – as well as small-scale flow units based on dune morphology and preservation - in outcrops and core in the Tensleep. This descriptive work is a necessary step in order to improve digital reservoir models run in Petrel, Eclipse, or other modeling software, or to develop new software that will improve estimates of recovery factors. The history of Wyoming includes much down-spacing of oil fields to produce bypassed reserves; and implicitly to correct original over-optimistic estimates of recovery factors that stipulated well spacing that was too great, and inappropriate EOR (usually waterflood) designs. This may be in part due to neglect of the heterogeneity produced by primary strata on oil recovery, particularly in reservoirs with low-viscosity, low-gravity oil. We have created simple models of the mechanics of the impact of eolian primary strata, mainly ripple and avalanche strata, on recovery factors in eolian reservoirs. Ultimately we plan to improve these models, and to undertake experimental work with rock samples. The plan long term is to develop engineering formulas that create more
reliable estimates of recovery factors that present methods allow. These will take into account the impact of primary strata anisotropy, cross-bed dip direction and effects of small reservoir flow units at the level of individual dunes.

Eolian petroleum reservoirs are not unique to Wyoming, although this state has an abundance of them; for example in Wyoming we have the Tensleep, Leo, Minnelusa Casper, Nugget, and Sundance Formations all of which produce oil and gas. Eolian reservoirs worldwide, such as the Rotliegend of the North Sea, commonly provide long-lived, high-volume production of both oil and gas, and importantly for Wyoming, provide new ideas from around the world that can be applied to similar reservoirs in Wyoming. As with any geologically defined unit, each oil/gas field has production characteristics peculiar to its history. However, common factors link most eolian reservoirs. Cross-stratification due to bedform migration creates preferred sweep directions and thus impacts recovery factors in fields of various maturities worldwide. Moreover, stacking of sand seas or bed forms through geological time will create distinctive flow units in subsurface petroleum reservoirs.

Selected References


Shell Exploration and Production, 2006, Play Based Exploration, A guide for AAPG’s Imperial Barrel Award participants, 50p.


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Abstract

The Tensleep Stratigraphy of Southeast Wyoming was measured and interpreted to develop new software that will improve estimates of recovery factors. The history of Wyoming includes much down-spacing of oil fields to produce bypassed oil. Oil production in Southeast Wyoming occurs in a variety of stages from primary through tertiary EOR, as well as various states of IOR (mechanical upgrades). There may further development opportunities in existing fields.

The Perimeter Upper Tensleep Formation at Flat Top Anticline near Medicine Bow, Wyoming.

Several measured sections have been used to create a model of the outcrop as a petroleum reservoir. Our observations on heterogeneity are helped by the fact that the lower half of the outcrop is oil-saturated. Variability in oil saturation among tight and permeable eolian strata are clearly visible. Ununatantd limitations and beds tend to be red or white, whereas oil-saturated portions of the outcrop are brown beneath a thin “whitish” layer of degraded oil.

REFERENCES CITED


Fryberger, S.G. and Schenk, C.J., 1988, Pin Stripe Lamination: A distinctive feature of modern and ancient eolian sediments: Sedimentary Geology, v. 55, p. 113-


Acknowledgements

Our work was made possible by many kind landowners and mineral owners in the region. We owe many thanks to D.L. Bailey and the folks at Two Rivers Ranch and Joe Horner of Horner Construction for access to the very important Flat Top Anticline. We also thank Steve Barret and Brian Titelman at the First Love and Sons Quarry near Laramie, Colorado, for access to important outcrops in the Lyons and Ingoldsby Formations on their property. Brenda and the folks at Lyons Sandstone Quarry in Lyons Colorado allowed access to important outcrops at their quarry. Thanks to Chinny Rock Ranch at Sand Creek for access to the classic Casper outcrops near the ranch and for their support of the University of Wyoming research for many years. We thank Shell for access to the Paradise Valley measured section in the Upper Tensleep Formation south of Laramie.

We thankChinaM. Conolly of ESRI for editorial review of this paper. Thanks also to the Wyoming Geological Association for use of figure from their various VQA publications cited in our paper (some of which go back many years!). Also, copious thanks to Shell Oil for use of one proprietary Play Based exploration concepts from the Guide for AAPG’s Imperial Barrel Award Participants. We thank Josh and Terry at the USGS Core Research Center in Lakewood, Colorado, for excellent look of core from Whites and Wraye (1981) Outcrops, which was very helpful in our study. We also thank Google for Google Earth views that were very helpful in recoding the results of our measured sections.

Reservoir heterogeneity caused by eolian primary strata

Most of the core and bio effects of eolian cross bedding and cross strata are due to the strong effects of interstratification between items in the regions leval with oil. The isolated and permeability structures dominate. We demonstrate this in the two figures above. The isolation of permeable laminations by light laminae may directly reduce recovery efficiency. These isolated laminations appear to have significant and important eolian effects on the overall geologic history of the study area. Light laminae (dune sand) can be identified as a distinct layer in the Permian Rotliegend Sandstone, Groningen gas field, Netherlands. Light laminae have probably been removed by the presence of oil. At very low amount of light laminae are indicated as at the B. F. Johnson North Field, the simulation of permeability does not reduce the porosity in the plays. A high permeability of the reservoir is indicated as the presence of oil. At very low amount of light laminae are indicated as at the B. F. Johnson North Field, the simulation of permeability does not reduce the porosity in the plays. A high permeability of the reservoir is indicated as the presence of oil.
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Regional Tensleep Stratigraphic cross section

- Wolque Energy Company Block-B Unit 1
  - NWSE sec. 18 T25N R76W
  - API 49-001-05393
- Memorial Operating
  - 102 ABC Unit 103 (Wertz)
  - SWNW sec. 7 T26N R89W
  - API 49-007-21004
- Union Oil of California
  - UPRR 44G-21
  - SESE sec. 21 T22N R75W
  - API 49-001-20033
- Gibson JW
  - Champlin 1-19
  - NENE sec. 15 T22N 75W
  - API 49-001-20033

Lower Permian (Wolfcampian) isopachs In Eastern Wyoming

- Black Hills
- Distribution and thickness of "interval A", "Wolfcampian", = Lower Permian rocks in Wyoming and adjacent areas, after Foster, 1958
- Thickness posted. Not every Tensleep penetration was used in our regional study. Older wells with poor logs or little data were omitted, as well as dense grids of intra-field wells, such as those at Wertz and Lost Soldier

Index map of the cross section shown on the right. Base map is comprised of the basement map of Wyoming, and Upper Tensleep isopachs

- Index map of Wyoming and counties, showing State database of Tensleep Penetrations (Tensleep, Casper, Minnelusa). Our study area is shown by red box with Upper Tensleep Thickness posted. Not every Tensleep penetration was used in our regional study. Older wells with poor logs or little data were omitted, as well as dense grids of intra-field wells, such as those at Wertz and Lost Soldier
The Sand Creek measured section was chosen at a locality that shows the transition upward from the red siltstones and arkosic fluvial sands of the Fountain Formation to the eolian dunes of the Casper Formation. The section is relatively complete, lacking only the upper 30 feet on the north of Casper below the Satanka red siltstones. There is a major change in total direction from northeast to southeast and southwest directed at unit 16. The section is a whole a classic “cleaning-upward” type, reflecting both the sorting of older fluvial sediments from the Fountain, and in the end, the arrival of sand transported long distances from the Permian sand sea to the north. The section is a whole a classic “cleaning-upward” type, reflecting both the sorting of older fluvial sediments from the Fountain, and in the end, the arrival of sand transported long distances from the Permian sand sea to the north.

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Eolian sediments

A carbonate pond deposit with clayey, ironstone bedding. This represents a local pond within an arid dune field where fine siltstones are shown to the right. The unit is interfingered with the Cretaceous upper Tensleep and the upper 30 feet or so of Casper above the Satanka red siltstones. There is a major change in total direction from northeast-directed to southwest and southeast-directed at unit 15. The section is a whole a classic “cleaning-upward” type, reflecting both the sorting of older fluvial sediments from the Fountain, and in the end, the arrival of sand transported long distances from the Permian sand sea to the north. At a nearby well south of the outcrop (Champlin 1-19), the Casper Formation has thinned and disappeared. This is typical of the Fountain in the Laramie Basin. It seldom extends very far northeast or southeast of the old Pennsylvanian-age uplifts.
Section 2

Measured sections


Eolian dune crossbedding in unit 11 (found in all three sections – arrow, dashed lines). This unit consists of several sets of slipface deposits with interbedded ripple strata. In all approximately 65-70 APS/RPS ratios on measured section 1. Dip of cross strata is toward the southeast, view to west. APS means “avalanche strata”; RPS means “ripple strata.”

Eolian sandstone deposits consisting of mixtures of avalanche (APS) and ripple (RPS) strata. In Unit 2, measured section 1. These sandstones are saturated with heavy, live oil. View to the west. Crossdip north-southwest, indicating wind from the north-southwest.

Eolian sandstone deposits showing fossiliferous limestone concretions in Unit 3, measured section 1. These sandstones are saturated with heavy, live oil. Dip of the crossdip is toward the northeast.

Eolian sabkha bedding consisting mainly of grainfall deposits in unit 10. Very thin are produced due to formation of salt ridges by precipitation of evaporites from near surface water table. This sequence records a long period of deposition, probably under conditions of being separated from the main continental source. Sandstones are brown, heavy oil. Dip of the crossdip is toward the west.

Mixed ripple and avalanche strata in Unit 2 of the Flat Top measured section 1. Note that the black-brown oil-saturated sand is broken up into many compartments by the cemented pin-stripe laminations from each stratum. This phenomenon creates microscopic barriers to flow in otherwise very porous and permeable sandstones in this image. View is to the northwest.

Sandstone of sabkha origin is found in Unit 2. It is a thin layer of sandstones with matrix more carbonate than sand, which is a rather unusual phenomenon in Wyoming. Deep-water conditions of the dominantly carbonate body, as zone observable. This unit represents carbonate reworking in an evaporitic lake or the salt-ridge (dry-land) building. It includes primarily to one source. Although the evolving carbonate and red beds of the Goose Egg Formation have marine affinities, an unconsolidated separate the Upper Tensleep section from the Lower Tensleep. Thus, there may be no interregional connection to marine deposits in the Upper Tensleep at Flat Top.

Highly saturated zone (grainfall) in unit 11 measured section 1. These sandstones are very porous and permeable. View is to the southwest, view to west. The sabkha encountered at Flat Top Anticline may be present in this well (arrow).
The Upper Tensleep Sandstones at White Rock Canyon, east side of the outcrop. Our 226-foot (partial) measured section begins in the Upper Tensleep, which in this area is roughly 400 feet thick, based on local well control. It was measured on the opposite (west) side of this cliff where access was easier. It begins about the middle of the Upper Tensleep and continues to the first carbonate in the Phosphoria (Goose Egg) Formation. See log this page for comparison. Note the variety of genetic units in terms of thickness, shape and crossbedding. This suggests that oil recovery factors from these genetic units would be equally diverse, mainly as a function of the arrangement of primary strata in each, as well as geometry, lithology etc. Thrust fault zone of deformation shown by red lines.

Fluvial red beds (conglomerates, sandstones, silstones) in unit 7. Close study reveals that 80% of this outcrop is ripple strata, despite the relatively steep dips visible on the image. An outcrop restored cross section with carbonate caprock.

A small fluvial channel with cemented wood and rip-up clastic bedding (between dashed lines). It is enclosed by dune sands above and below. Unit 18.

Steep cliff above goes to top of section units 19-23. Upper part of the measured section, consisting mainly of silty sands with some calcereous and small thickness of relatively clean, coarse fluvial sandstones.

View of the outcrop from the east side reveals complexity of individual genetic units, most of which probably act as flow units in subsurface reservoir. Red fluvial sand is indicated by arrows.

Closeup study reveals that 80% of this outcrop is ripple strata, despite the relatively steep dips visible on the image.

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Steep cliff above goes to top of section units 19-23. Upper part of the measured section, consisting mainly of silty sands with some calcereous and small thickness of relatively clean, coarse fluvial sandstones.

Top Upper Tensleep
An overview of the measured section at Paradise Valley. It consists of an eolian sequence sandwiched between two marine carbonates (not visible in this image). Units at the base and top of the section are marine limestones of the Tensleep (Casper). Dune sequence in this outcrop has largest dunes at base, smaller, more complex sets of dunes, sabkhas and marine shoreline deposits, including carbonates higher-up. Dashed white line shows base of sabkha (Unit 5).

Lower part of the Paradise Valley measured section with dune bedforms, where Nick Jones is seated taking notes. Generally, bedforms become smaller up-section. This sequence (see measured section) would make a complex petroleum reservoir with numerous distinctive flow units. The best flow units are probably the dunes shown here at the base of the cliff below the dashed line, due to a preponderance of permeable avalanche strata.

Close-up view of a set of avalanche strata on a dune slipface at the base of the measured section. This is Unit 1 of the measured section. Overlaid unit shows the exposed bounding surface consists of stacked sets of units of Unit 2, which overall are relatively unweathered. The general pattern of the dunes appears to be a sequence of large, simple, bedform sets of dunes at the base, with smaller, more complex sets of dunes higher-up. The general trend is for the dunes to become smaller up-section.

A boundary of course sand grains within white oval is a typical of eolian sandstone facies. The coarse grains at the base are formed by wind scour of finer sand and silt. Many of the coarse grains are light-colored.

A monolayer of coarse sand grains typical of eolian sedimentation. The coarse-grained lags are formed by wind scour of fine and medium sand. Many of the coarse grains are light-colored.

The marine limestone that forms the base of the dominantly eolian rocks of the measured section is the background. This limestone contained shell fragments.

Stratigraphy of the Casper Formation near Laramie. The measured section was in the upper, Permian part of the Formation where the Benton has been identified. The measured section is characterized by a sequence of eolian dunes, with a basal unit of marine limestone and a complex sequence of sabkha and eolian deposits, including carbonate high-up. The measured section shows three sets of calcrites (Unit 1).

Stratigraphy of the Casper Formation near Laramie. The measured section consists of an eolian sequence sandwiched between two marine carbonates. The underlying bounding surface consists of stacked sets of units of Unit 2, which overall are relatively unweathered. The general trend is for the dunes to become smaller up-section.

A sandstone with distinct eolian ripples. The ripples are approximately parallel to the bedding planes, indicating that the wind direction was consistent during deposition. The ripples are sub-parallel to each other, suggesting that the wind was blowing in a consistent direction. The ripples are well-defined and have a consistent orientation, indicating that the wind was blowing in a consistent direction. The ripples are well-defined and have a consistent orientation, indicating that the wind was blowing in a consistent direction.

Stratigraphy of the Casper Formation near Laramie. The measured section consists of an eolian sequence sandwiched between two marine carbonates. The underlying bounding surface consists of stacked sets of units of Unit 2, which overall are relatively unweathered. The general trend is for the dunes to become smaller up-section.

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Upper Fountain-Ingleside Fm Lien Quarry and Owl Canyon Northern Colorado

Below: Fountain-Ingleside outcrop: locality of our measured section along U.S. Highway 287

Our section (shown to the right on this page) begins in the Upper Fountain Formation. The transition to Ingleside is in the transition is gradational. To our surprise we found considerable eolian sand and sand dunes within the dominantly fluvial Fountain. These commonly had a pink color. One of these units is marked by the arrow on the left.
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Tensleep stratigraphy

### Upper Tensleep thickness

Upper Tensleep thicker than 250 feet is shown in yellow, thinner than 150 feet is shown in orange. Thick Upper Tensleep is associated with the Hanna Basin, Northern Laramie Basin and SE Laramie Basin. Thin in the Laramie Basin follows the Cheyenne Belt of deformation.

### Total Tensleep thickness

### Hanna Basin

### Green areas on this map enclose regions with oil or gas shows in the Upper Tensleep, based on Wyoming Oil and Gas Commission records of production, drill stem tests, and limited core and sample data. This map also shows major faults in red from the state geological map, and structure contours are shown on the top of the Upper Tensleep. There are distinct, structurally defined shows in Wertz, Atlantic Rim, Baggs, Medicine Bow and Quealy Dome regions.

- Wertz-Lost soldier
- Atlantic Rim
- Baggs
- Medicine bow
- Quealy Dome

### Sybille carbonate-evaporite thickness

The Sybille carbonate-evaporite sequence of the Goose Egg Formation immediately overlies the Satanka Shale. The thickness is a good indication of post-Tensleep tectonics. Thick Sybille is present in the Lost Soldier-Wertz area, Hanna Basin, and a NE-SW trending area defined by faults in the Laramie Basin that may indicate early fault movement. On this map, thicks are indicated by purple shading, thins, by orange.

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*This Figure after McKee, E.D. et al., 1967.*
Play Based exploration (PBE) and Common Risk Segment (CRS) evaluation

Play Based exploration is a method used to build-up, then leverage regional understanding of basins and petroleum systems, in both mature and immature basins, to the specific geological plays they contain. The benefits lie in providing an early focus on a range of exploration or production activities.

The multi-scale approach (from basin to prospect scale within a petroleum system) provides greater technical rigor, and hence quicker, more confident E and P decisions, even with partial or incomplete data. Now play growth, or rejuvenation of older plays is enabled by the creativity and innovation that can be unleashed most effectively at the level of basin or petroleum system understanding.

The PBE methodology is encapsulated in the “Exploration Pyramid” (see cartoon on right), where the initial focus is on the basics - the determination and description of the regional context and the basin framework leading to an understanding of the working petroleum system(s).

Petroleum system understanding forms the basis for the subsequent play focus - quantifying the various aspects of the system within each play, and using tools such as common risk segment mapping to highlight sweet spots within each play. The focus of the EORI CRS mapping within PBE method is shown by the red dots and arrows on the figures on this page. CRS mapping can involve quantitative Possibility of Success (PoS) estimates or reflect “low risk” versus “high risk” determinations made using the regional geological overview. These estimates are stacked in a program such as ArcGIS (see diagrams at bottom of page). Areas in which reservoir, charge, and trap are best, and overlap geographically, will focus both exploration and production opportunities. EORI currently works at the CRS play segment level; we do not target prospects per se, although some attractive ideas occasionally emerge from our databases.

When the CRS “low risk” areas have been mapped by EORI and where possible, quantified, the focus shifts to operators who may choose to create more detailed geological and geophysical analysis to define prospects within each play, and build a portfolio, including making estimates of volumetrics, risk, and uncertainty. It is at this stage the seismic data and consideration of field level petrophysics come under consideration; especially in the evaluation of field acquisition or development choices.

Play based exploration (PBE), admittedly, requires up-front investment of time if the regional play framework has not already been defined. However, that investment will be repaid by swifter and simpler assessment of individual prospects, and in the quality of subsequent decisions by industry.

This page was greatly benefited by the Shell Exploration and Production Play Based Exploration guide. We express our thanks.

The working definitions shown above are used in PBE analysis of this poster. Our work focuses on CRS mapping of the Upper Tensleep in Southeast Wyoming at the play segment level. We also use constructive elements building from the bottom of the list, including the petroleum system and play to weigh evaluation of individual play segments.

The logic of sweet-spot identification involves the stacking of positive geological indicators that collectively fulfill the requirements for the existence of an oil field or a very productive region of a basin. The common overlap area in which all factors are positive, or “low risk” in terms of presence is a natural sweet spot. This approach is usable at basin, CRS play segment, and prospect scale.

Concepts and illustrations on this page after Shell Exploration and Production, Play Based Exploration: A Guide for AAPG’s Imperial Barrel Award Participants, with thanks.
Tensleep CRS Overview

Common Risk Segments (CRS) are geological risk elements for petroleum exploration or development (commonly reservoir, source, and trap) that have a definable, quantifiable, and geographically reproducible distribution. The assessment of CRS segments is commonly a matter of judgment by an experienced geologist about relative risk in terms such as “low risk of no charge” versus “high risk of no charge”, for example. These understandings can also be expressed as possibilities of success (PoS) as percentages from zero to 100, or statistical categories such as P5-P50-P95 for probabilistic estimates. In this report we evaluate risk in terms of a common set of geological risk factors perceived to be typical of a region (such as the Atlantic Rim), but our values are relative, that is, expressed as “high-risk-low risk” etc. and not quantified further.

These understandings can also be expressed as possibilities of success (PoS) as percentages from zero to 100, or statistical categories such as P5-P50-P95 for probabilistic estimates. In this report we evaluate risk in terms of a common set of geological risk factors perceived to be typical of a region (such as the Atlantic Rim), but our values are relative, that is, expressed as “high-risk-low risk” etc. and not quantified further.

The maps on this page illustrate elements used in construction of a basic “common risk segment” map of the Upper Tensleep Formation in Southeast Wyoming. The combined CRS map is displayed immediately to the right of this text. Not surprisingly, the complete CRS map for “low risk” lacks existing Tensleep production (red areas on map are oil fields). However, study of the maps depicting reservoir quality, structure, and charge (shown) reveal why the fields are where they are, and highlights trends that would not be obvious without this technique. This may perhaps encourage further work in these regions, and this may lead to further discoveries even in this mature petroleum province.

Tensleep Formation Common Risk Segment Maps

Upper Tensleep Trap Risk

Combined Upper Tensleep Common Risk Segment (CRS) map. Green areas show regions with the best chance to find new production (lowest risk). Blue areas show moderate risk. Red fractured areas show high-risk areas, mainly regions such as the Hanna Basin with deeply buried, tight Tensleep, or areas with insufficient evidence for robust structural traps. State of Wyoming basement map as background.

Southeast Wyoming seismic trade data

Availability of trade seismic data in southeast Wyoming (sample). Black lines show 3D data, red polygons show 3D surveys. These data are superimposed on the combined CRS map for the region based on this study (see maps on this page). Map is background is the Wyoming basement map. Seismic data is courtesy of SEI Seismic Exchange data brokers in Houston and Denver. Other trade data is available.
The Quealy Dome low-risk CRS play segment is characterized by numerous free oil shows on drill stem tests and Tensleep production of Quealy, Herrick, and Little Laramie oil fields. The stratigraphy - as visible on the Wyoming Geological Survey basement map, and as subsurface contours (based on wells) - is complex. Faults, anticlines, closures, overthrusts and fault rips may remain. The complexity noted by Stone (1995) is impressive, and one wonders if older 2D seismic data has been processed in ways that image this complexity properly. The source rock may or may not be the Phosphoria Formation in this region.

The Lost Soldier-Wertz low-risk CRS area is notable for those two very large Tensleep fields, as well as a few smaller ones, such as Mahoney Dome. It is an interesting question whether there might be any significant undiscovered Tensleep accumulations in an area that has been so intensively explored. Probably this area, which is low-risk geologically, awaits the “new idea in an old area” concept if it is to contribute more reserves. It might be worth a review of older seismic to make sure that processing and acquisition parameters are up-to-date, and that no prospective thrust faults have been overlooked, or structural closures incorrectly mapped due to time-depth calculation errors in original processing.

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Tensleep oil fields in SE Wyoming are mainly structural traps. However, it is likely that recovery factors from these fields are heavily influenced by eolian reservoir heterogeneity at multiple scales that we observed repeatedly in core and interpreted similar to eolian reservoirs worldwide (Fryberger and Hora, 2016). Evidence for some of this heterogeneity is presented on this slide, from primary units to larger scale, sandbodies and genetic units that are obviously flow units due to manifest porosity differences observed in cores.

**EOR status in Southeast Wyoming Examples**

Tensleep producing area

**Preferred flow directions created by anastomosing permeability at small (dominant) scale in available and ripple strata.** These are predicted using data from the 1D permeameter measurements at the Middle Jurassic Page Sandstone (chosen in image below). Red arrows are proportional in length to directional permeability along primary strata. White arrows do not show the sediment of reservoir efficiency and recovery factor due to micro-traps for oil created by primary strata. After Chandler, et al. 1989.

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**Wertz 46**

An Upper Tensleep genetic unit was not perforated, despite high oil saturation. Oil may have been swept by an adjacent injection producer well, or not displaced. Unit appears isolated stratigraphically from perforated unit below.